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(54) Colour television signal encoder

(57) A repetitive signal is switched by digital colour-separation signals and the switched repetitive signals and the colour-separation signals are summed. The repetitive signal has preferably the same frequency as the colour sub-carrier frequency or is an integral sub-multiple of it.

In a single-bit digital colour-separation signal version, in the red channel NAND-gates (42_{Ru}, 42_{Rv}) have respective repetitive signals (50_u, 50_v) and the red colour-separation signal (48_R) applied to their inputs. The outputs of the NAND-gates (42_{Ru}, 42_{Rv}) and the colour separation signal (48_R) are connected to respective current-defining means (58_{Ru}, 60_{Ru}; 58_{Rv}, 60_{Rv}; 58_R, 60_R) and the resultant currents are fed to a summing amplifier (56), together with similar blue and green channel signals (70).

The repetitive signal is preferably a square-wave, but may be, for instance, a rectangular wave. Various vector relationships between the repetitive signals for each colour are possible, to a large extent being dependent on the relationship between the repetitive signal fundamental frequency and the colour sub-carrier frequency.

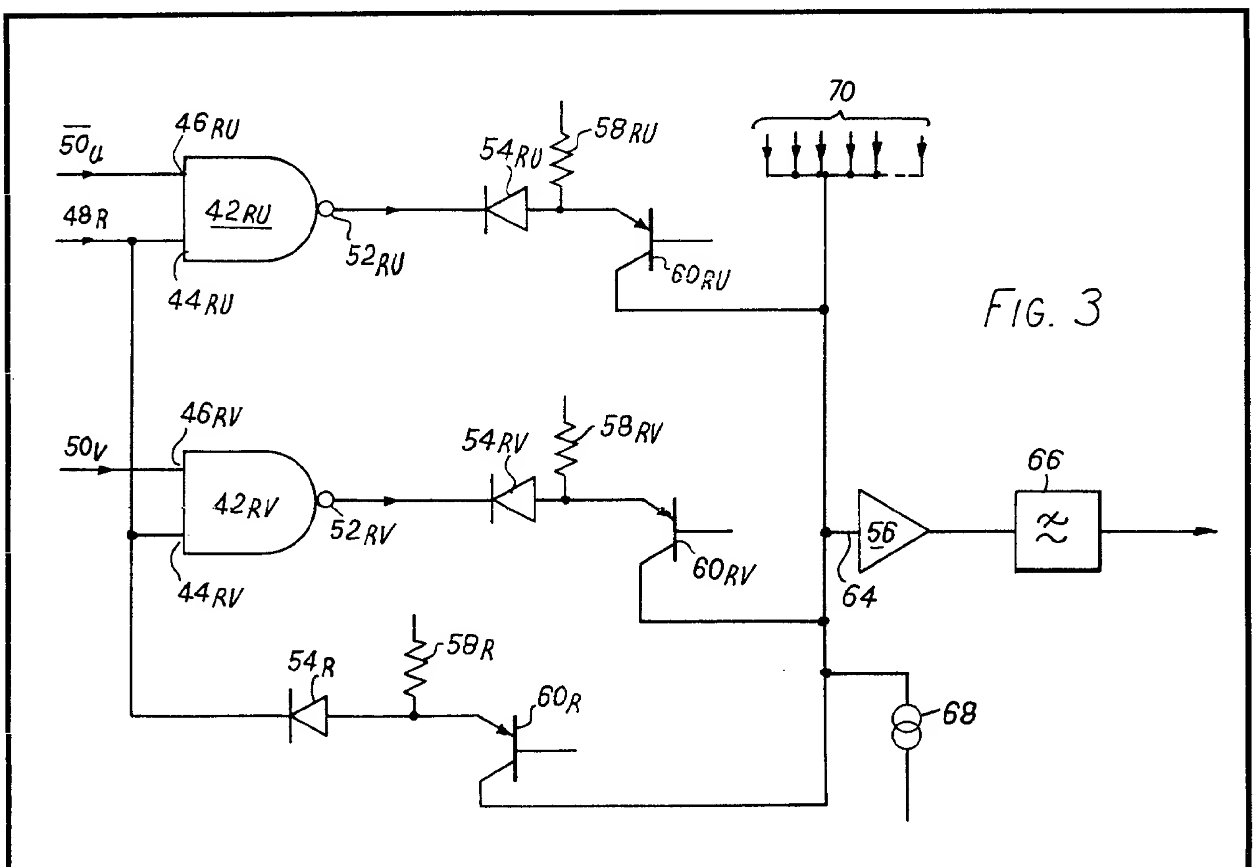

FIG. 3

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2029154

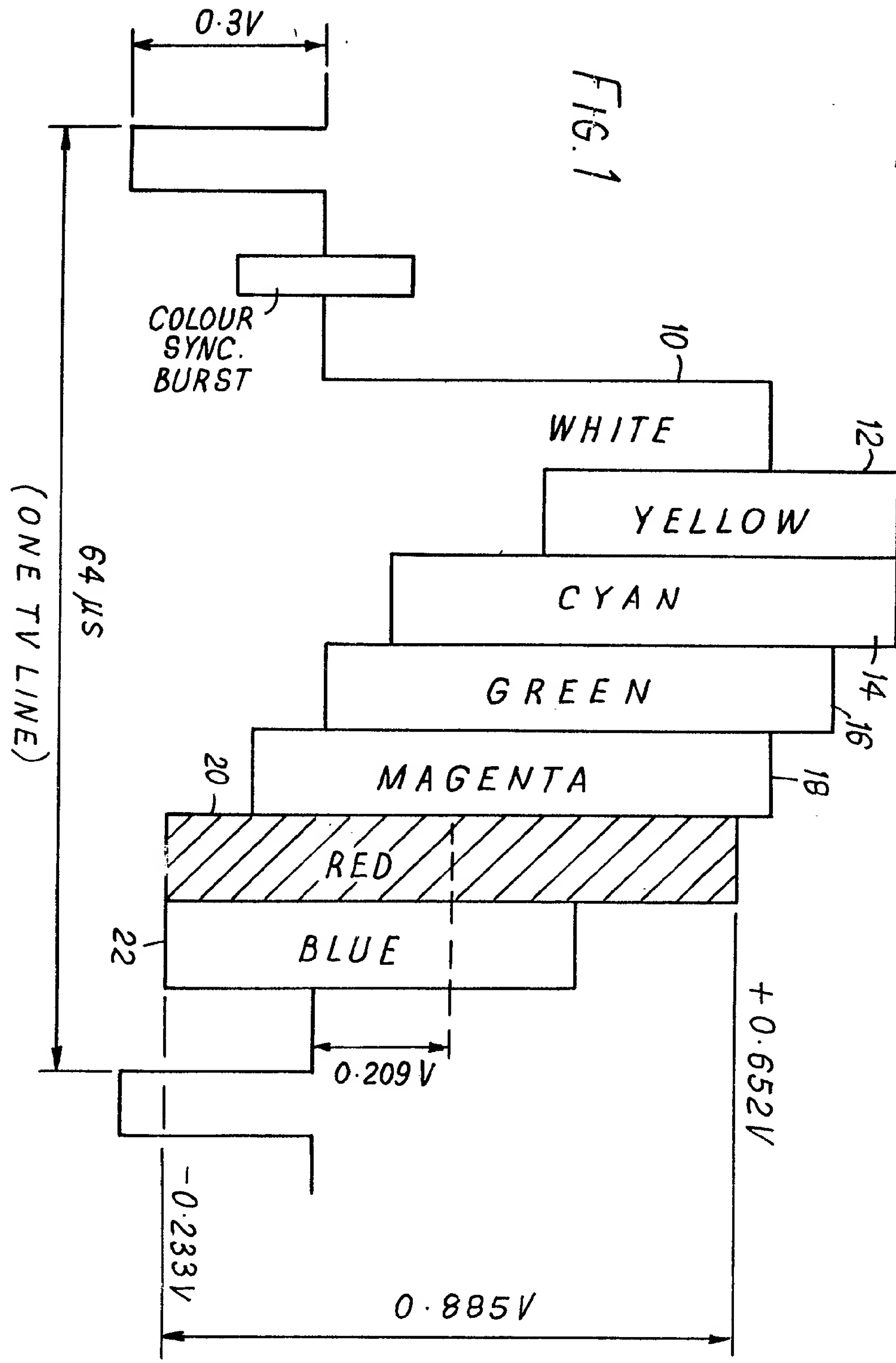


FIG. 1

2029154

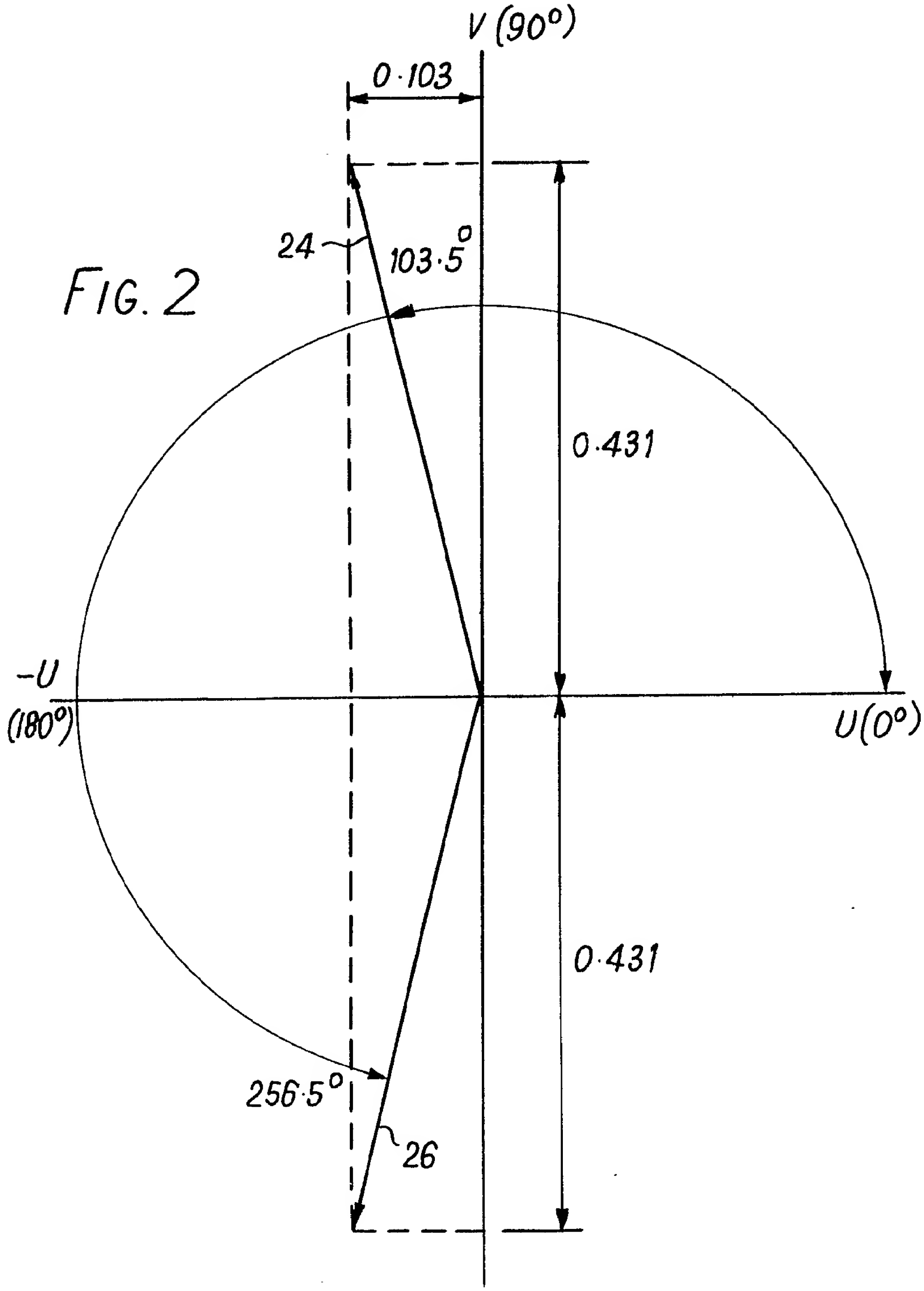


FIG. 2

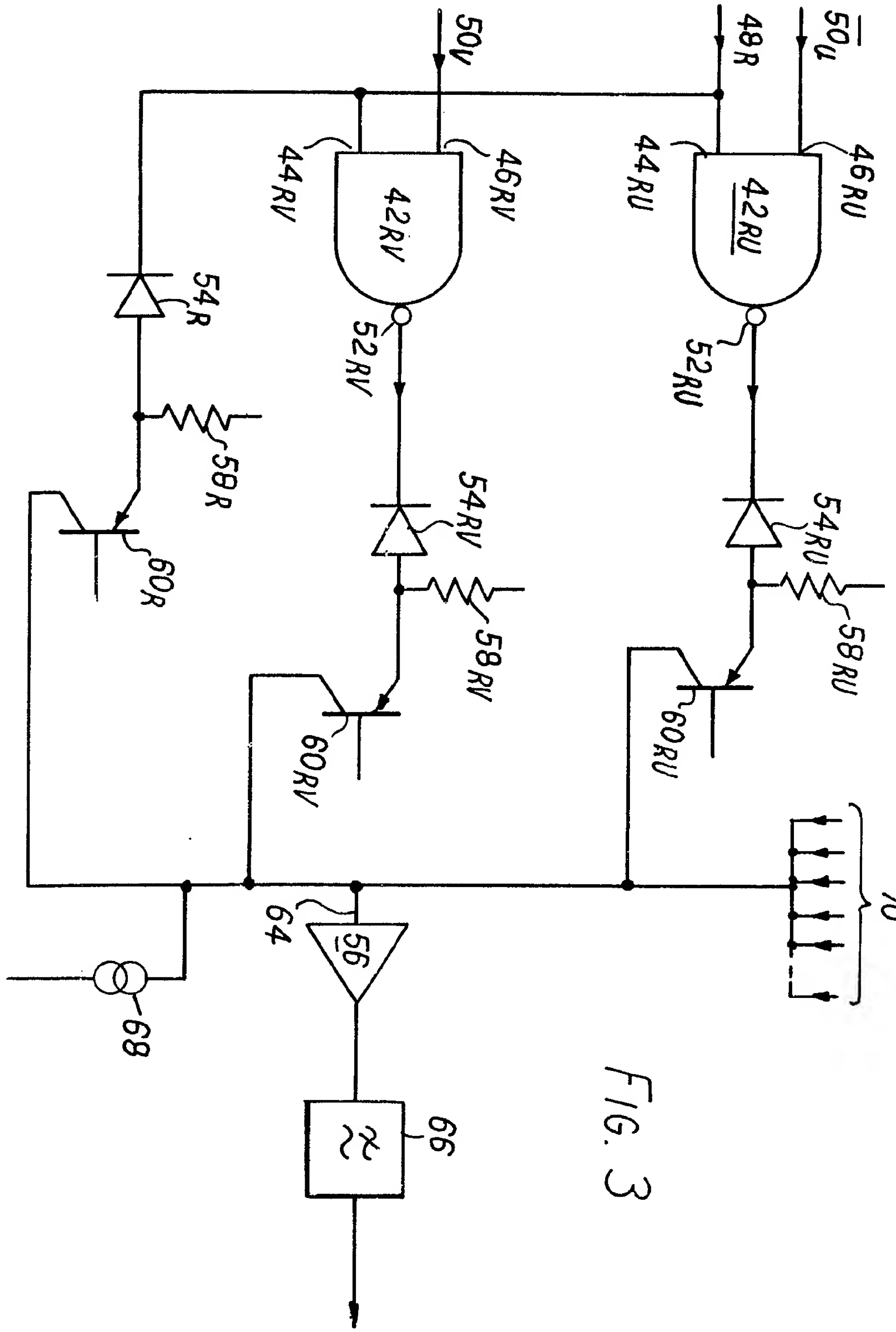

50V
48R
$\overline{50_U}$
44RV
42RV
46RV
44RU
42RU
46RU
54R
52RV
52RU
58R
54RV
54RU
60R
58RV
58RU
60RV
60RU
70
64
56
68
66

FIG. 3

2029154

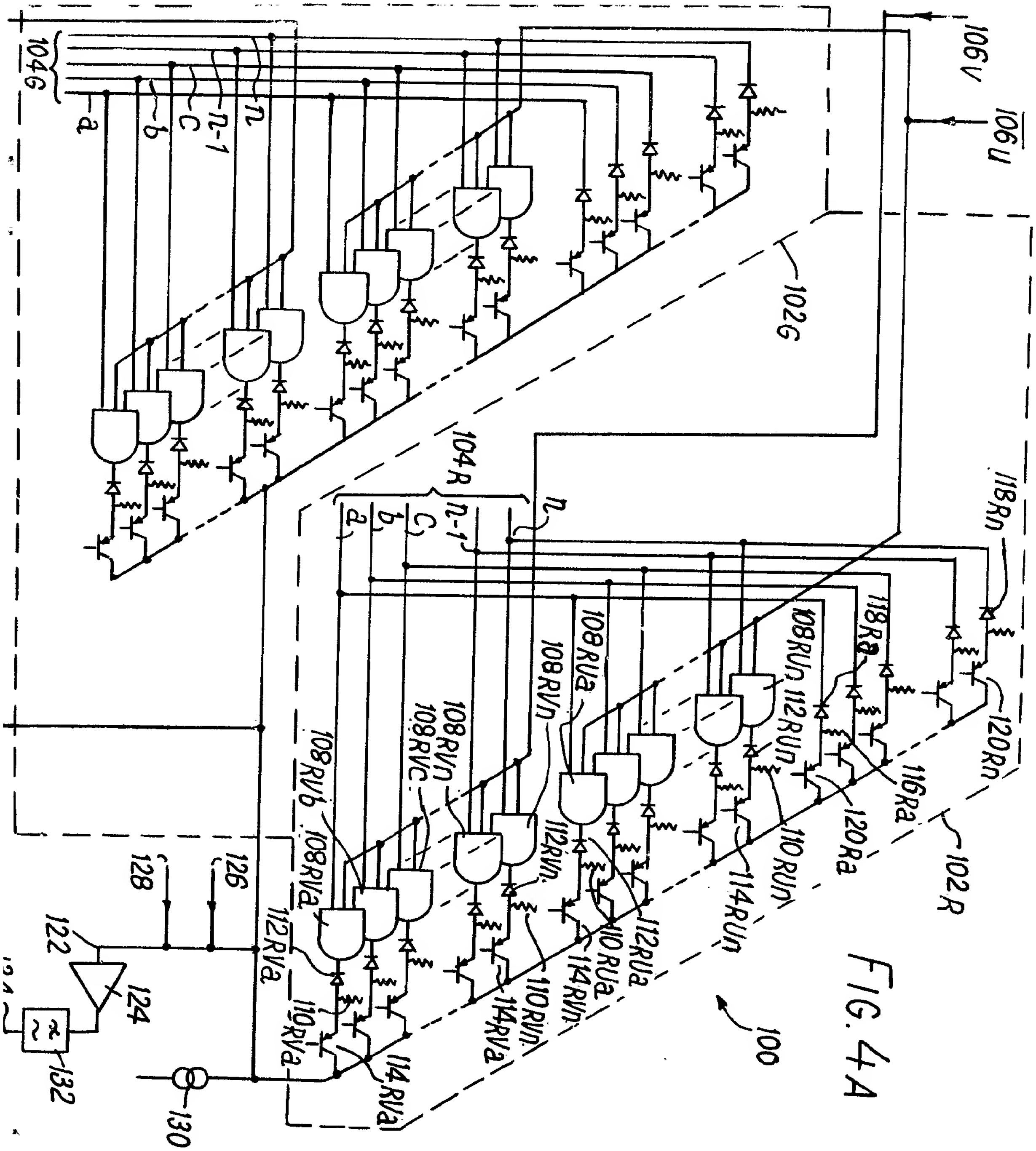


FIG. 4A

4/10

2029154

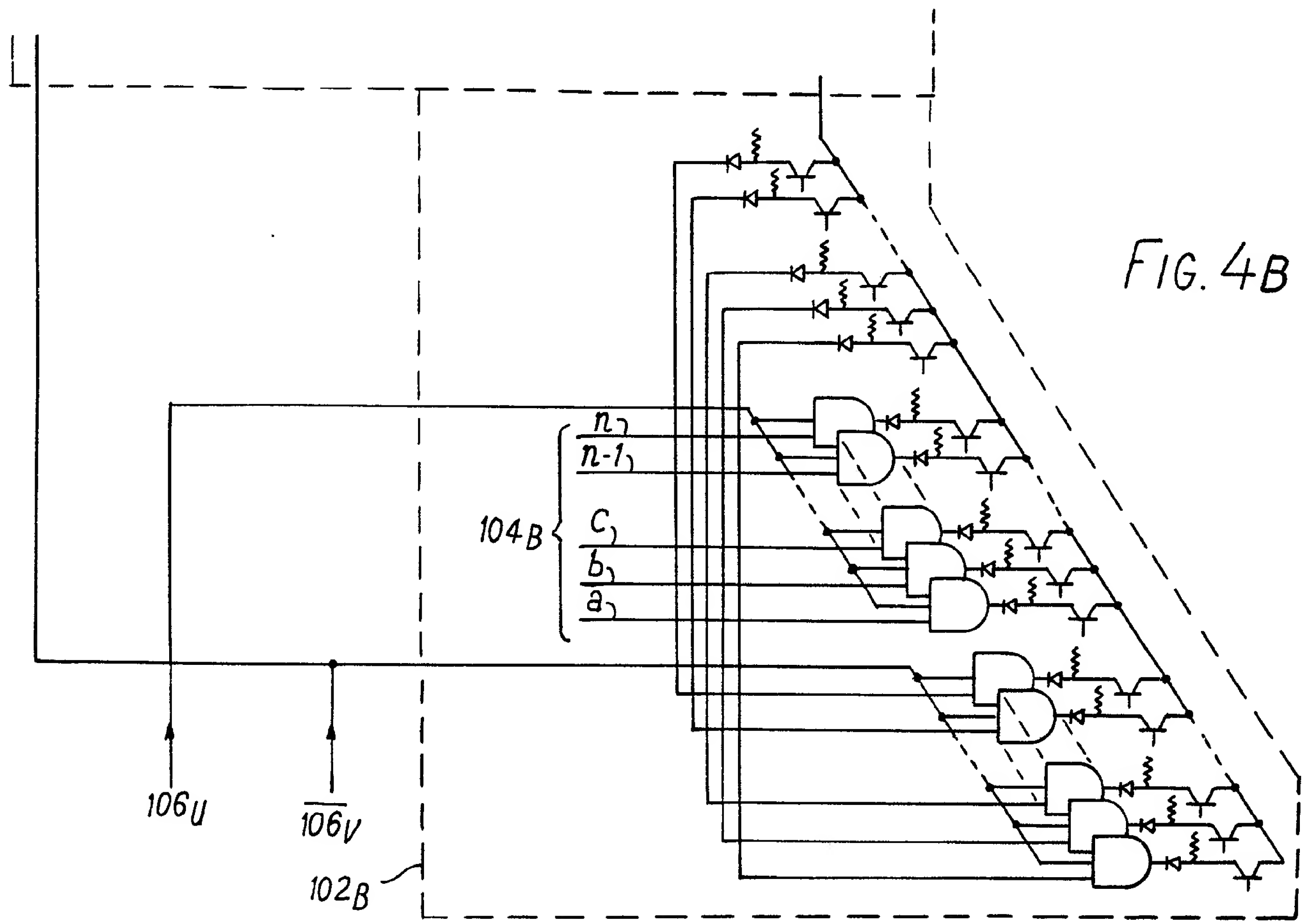
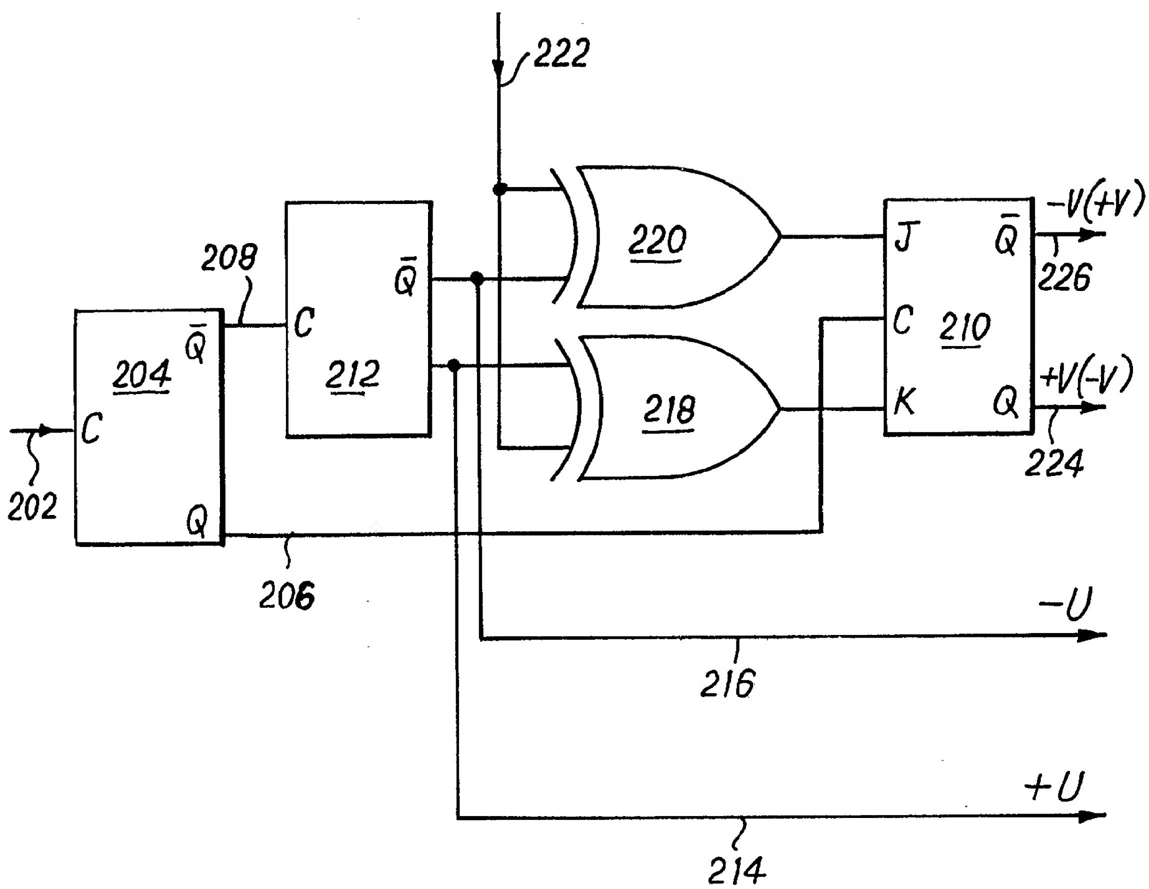


FIG. 4B

5/10

FIG. 5


222
220
218
208
C
Q̄
212
204
Q̄
C
202
Q
206
J
Q̄
C
210
K
Q
-V(+V)
226
+V(-V)
224
-U
216
+U
214

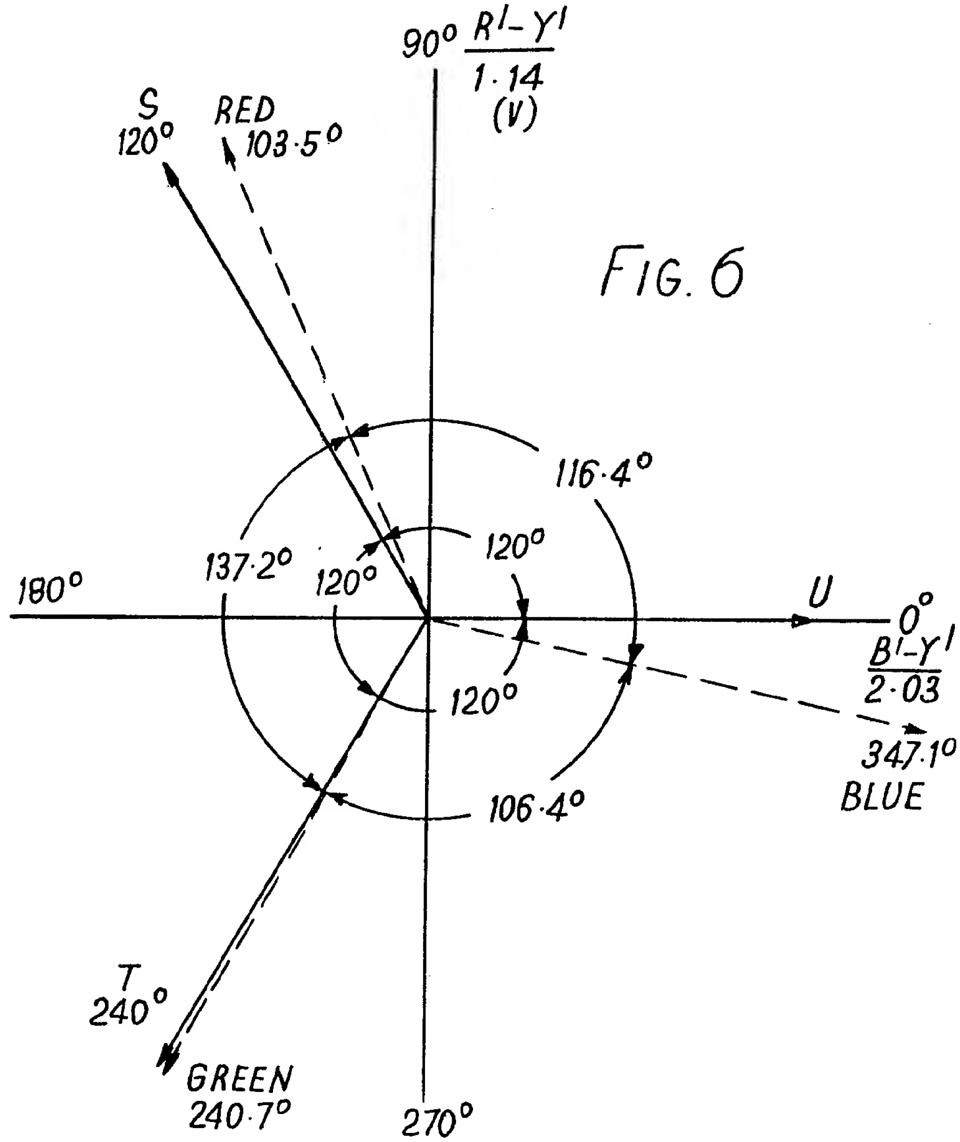
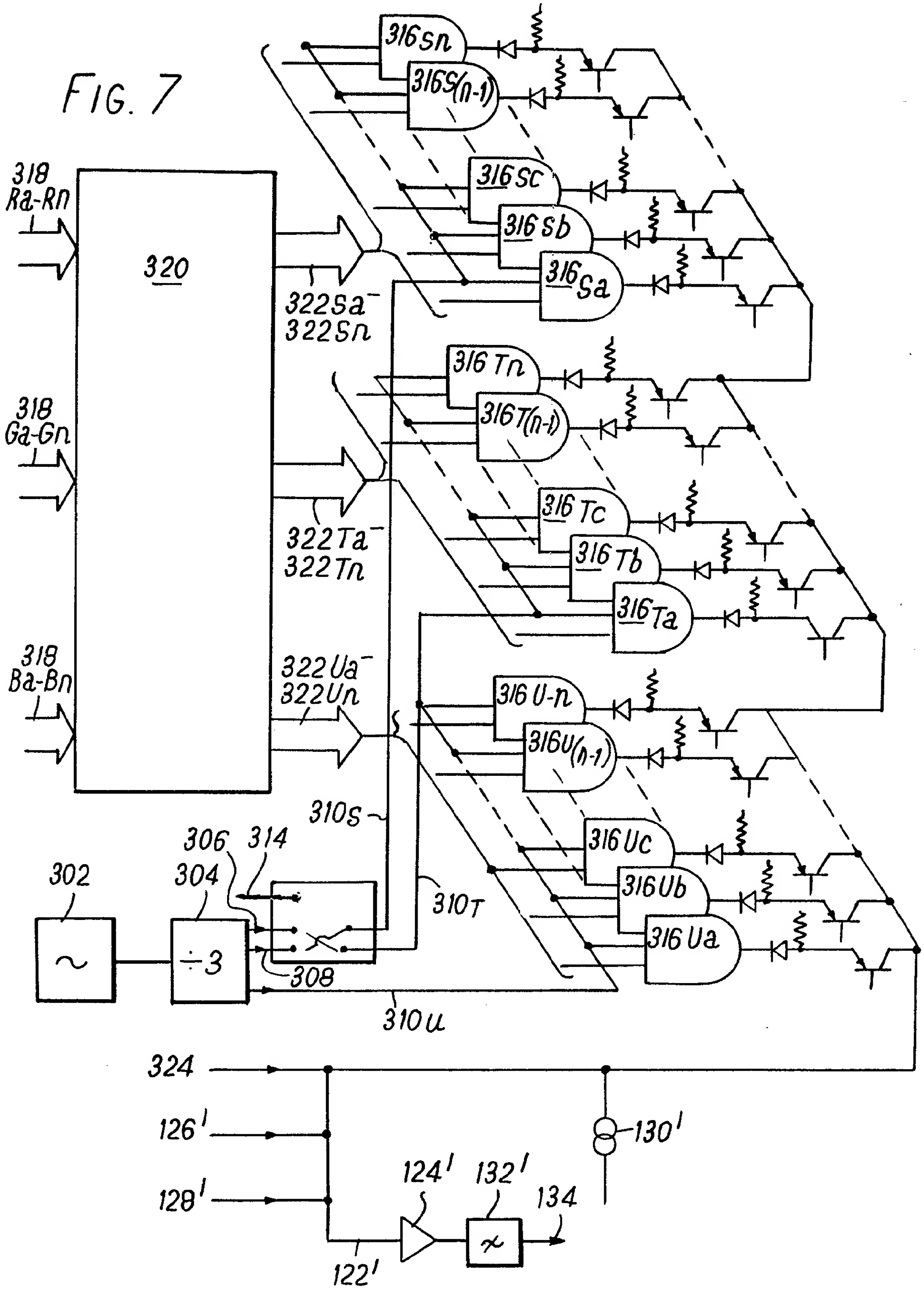

90°
R'–Y'
1·14
(V)
S
120°
RED
103·5°
116·4°
120°
137·2°
120°
180°
U
0°
B'–Y'
2·03
120°
347·1°
BLUE
106·4°
T
240°
GREEN
240·7°
270°

FIG. 6

FIG. 7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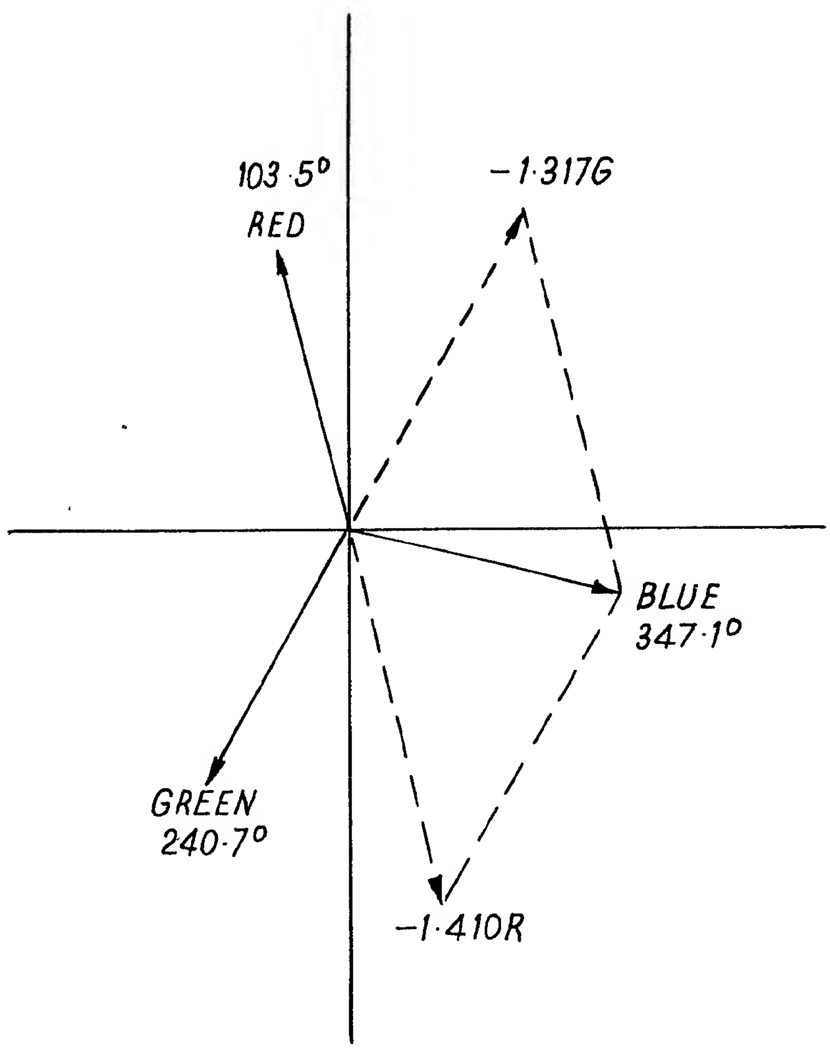
316s(n-1)
316sc
316sb
316sa
318
Ra-Rn
320
322Sa-
322Sn
316Tn
316T(n-1)
318
Ga-Gn
316Tc
316Tb
316Ta
322Ta-
322Tn
318
Ba-Bn
322Ua-
322Un
316U-n
316U(n-1)
310s
316Uc
316Ub
316Ua
302
304
306
314
310T
308
310u
324
126'
128'
130'
124'
132'
134
122'

FIG: 8



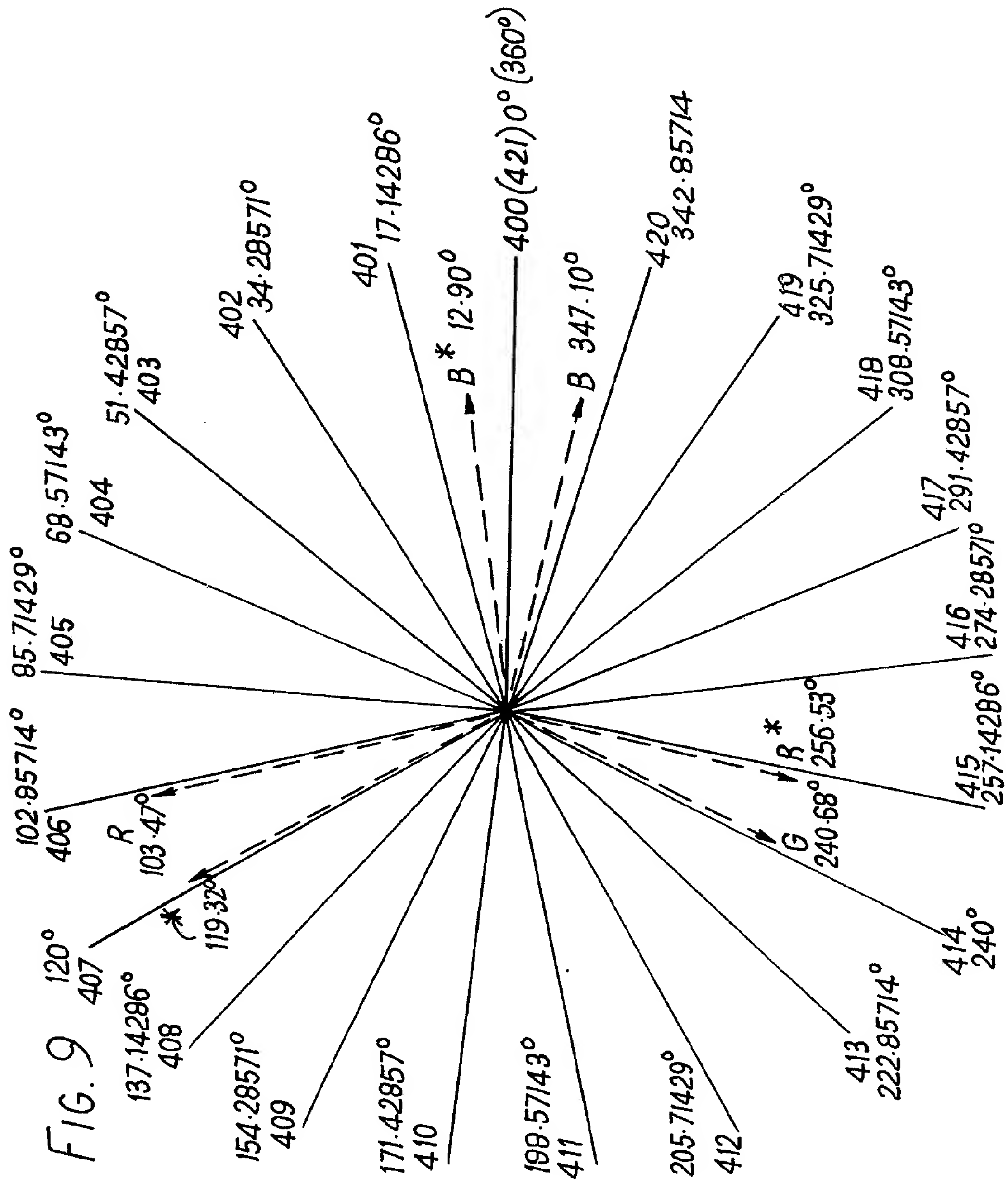

400 (421) 0° (360°)
401 17.14286°
402 34.28571°
51.42857° 403
68.57143° 404
85.71429° 405
102.85714° 406
120° 407
137.14286° 408
154.28571° 409
171.42857° 410
188.57143° 411
205.71429° 412
413 222.85714°
414 240°
415 257.14286°
416 274.28571°
417 291.42857°
418 308.57143°
419 325.71429°
420 342.85714
B* 12.90°
B 347.10°
R 103.47°
* 119.32°
R* 256.53°
G 240.68°

FIG. 9

SPECIFICATION

Colour television signal encoding

The present invention relates to the encoding of colour television signals from digital colour separation signals, or digital or analogue monochrome signals.

The present invention has as its object a reduction in the numbers of digital to analogue converters, balanced modulators and inductors in PAL and NTSC encoders, reductions in the setting-up procedures and long-term drift, and an improvement in the reliability of such devices. Additionally, fabrication as a single integrated circuit is possible, and as no tuned circuits are used in the parts of the circuit where such switching is necessary, direct switching from PAL to NTSC operation, and vice versa, is possible.

According to the present invention there is provided a method of producing a colour television signal by switching a repetitive signal according to colour-separation signals, and summing the switched repetitive signal and colour separation signals.

The repetitive signal has preferably a fundamental frequency at the colour sub-carrier frequency.

Alternatively, the repetitive signal is an integral sub-multiple of the colour sub-carrier, and the summed signals are passed through a band-pass filter whose pass-band is centred on the colour sub-carrier frequency.

Preferably the repetitive signal is a square-wave.

A "repetitive signal" used herein is defined as a signal having at least a fundamental frequency and possibly harmonics thereof, so that the waveform of the signal over one cycle at the fundamental frequency is repeated at the fundamental frequency.

The phases of the various primary and complementary colours in the NTSC signal are seldom quoted with an accuracy of better than 1°. In PAL they are often quoted to 0.2°, but 0.5° is perhaps more usual. The IBA Code of Practice for TV Studio Equipment states that an error of ± 0.5° "has a high probability of not being exceeded" in practice.

Since it will seldom be necessary to operate a system with two or more colour encoders in tandem, and since in a digital encoder one can expect great stability, it would seem reasonable to aim for phase accuracy of 0.2° if it can be obtained; or at least some accuracy between 0.1° and 0.5°.

The criterion against which phase errors are judged should be the theoretical values derived by calculation from the system standards, and not the published values, to avoid incorporating two lots of rounding errors.

Theoretical Phase Angles for Red, Green and Blue in NTSC and PAL

The NTSC (or PAL) luminance signal E'_Y, abbreviated here to Y, is defined by the equation $Y = 0.58G + 0.299R + 0.114B$ in which G, R and B are used in place of the conventional E'_G, E'_R and E'_B for brevity, to represent the gamma-corrected green, red and blue signal voltages respectively.

If colour-difference signals $R-Y$ and $B-Y$ are formed for full-amplitude primary colours red, green and blue, then

	R	G	B	Y	$(R-Y)$	$(B-Y)$
Red	1	0	0	0.299	+0.701	−0.299
Green	0	1	0	0.587	−0.587	−0.587
Blue	0	0	1	0.114	−0.114	+0.886

To avoid overload, while at the same time making the best possible use of the signal amplitude range available in the transmission system, these colour-difference signals are scaled by factors of 1.14 and 2.03 respectively, giving the two chrominance components below for each primary colour:–

	R−Y (= *V*)	*B−Y* (= *U*)
	1.14	2.03
Red	+ 0.614912	− 0.147290
Green	− 0.514912	− 0.289162
Blue	− 0.100000	+ 0.436453

In PAL these scaled colour-difference signals are termed *V* and *U*, as indicated. In both PAL and NTSC they are used to modulate colour subcarriers in quadrature which are then combined together and added to the luminance signal for transmission, neglecting here the refinement in NTSC of transformation to *I* and *Q* to enable different bandwidths to be used for high- and low-visibility colour detail (this is not a feature of PAL, except as a permitted option). The amplitudes and phases of the resultants are obtained by the usual rules for the composition of vectors.

$$\text{amplitude} = \sqrt{U^2 + V^2}$$

and phase

$$= \arctan \frac{U}{V}$$

referred to the *U* axis. For completeness, the actual values are

	Amplitude	Phase, degrees	
Red	0.632305	1.03.470280	(256.529720)
Green	0.590548	240.682497	(119.317503)
Blue	0.447762	347.095146	(12.904854)

The phase values shown in brackets are those for the conjugate lines in PAL, the alternate lines on which the sign of the *R−Y* component is reversed.

In what follows, the main concern is with phase accuracy, since amplitudes can in principle be defined to any desired accuracy by sufficiently precise choice of weighting factors in the Digital-to-Analogue conversion. Since any other colours can be expressed as a linear combination of red, green and blue, it is sufficient to consider these three alone.

Primary interest in what follows is in the angles between the three vectors. These are

Blue/Red	116.375134 degrees,	or 0.323264 of circle.
Red/Green	137.212217 degrees,	0.381145 of circle.
Green/Blue	106.412649 degrees,	0.295591 of circle.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 shows a PAL Colour-bar test signal format;

Figure 2 shows the resolution of the red vector of the signal shown in Fig. 1 into V and U components;

Figure 3 shows a partial circuit diagram of a first embodiment of an apparatus according to the present invention;

Figures 4A and 4B show a circuit diagram of a second embodiment of an apparatus according to the present invention; and

Figure 5 shows a circuit diagram of an apparatus for generating the colour sub-carriers in quadrature used in the apparatus of Fig. 3 or Figs. 4*A* and 4*B*.

In Fig. 1 is shown a typical PAL Colour-bar test signal waveform 10 of maximum contrast and saturation. The rectangles 12, 14, 16, 18, 20 and 22 are the envelopes of the colour sub-carrier for the yellow, cyan, green, magenta, red and blue bars respectively and the red bar signal 20 will be considered in particular.

Referred to a 0.7 volt black-to-white signal amplitude, the red-bar signal must have a

luminance level, the centre-line of the rectangle, of 0.209 volts and a peak-to-peak sub-carrier amplitude of 0.885 volts with a phase-angle of 103.5° and 256.5° from the reference axis (*U*-axis) on successive lines. The vector diagram representation of this is shown in Fig. 2.

If as shown in Fig. 2 the red chrominance signal vectors 24, 26 are resolved into *U* and *V* components, the *U*-component is -0.203 volts and the *V*-component is ± 0.861 volts peak-to-peak sub-carrier, the + and − signs for the *V*-component relating to alternate TV lines.

By Fourier Analysis a square-wave of amplitude $\pi/4 = 0.7854$ has as its fundamental frequency component a sinusoid of unity amplitude. Hence the fundamental component of the sum of square-waves of amplitude $-\pi/4 \times 0.206$ volts (0.162 volts) in *U*-phase and $+\pi/4 \times 0.861$ volts (0.676 volts) in *V*-phase provides one of the red chrominance signal vectors 24, 0.885 volts peak-to-peak amplitude and 103.5° phase. Similarly the other red chrominance signal vector 26, 0.885 volts peak-to-peak amplitude at 256.5° phase, is the fundamental component of the sum of square-waves of amplitude -0.162 volts in *U*-phase and -0.676 volts in *V*-phase. A similar analysis can be applied to the other primary colour bars green, and blue, 16 and 22 respectively of the waveform 20 of Fig. 1.

The yellow, cyan and magenta bars, 12, 14 and 18 respectively are produced by simultaneous production of red and green, blue and green, and red and blue bars respectively. A white bar is produced using red, green and blue bars simultaneously, where the chrominance components cancel, and a black bar is produced by an absence of luminance and chrominance signals.

In the apparatus described with reference to both Figs. 3 and 4 below corresponding items will be identified with the same reference number, with an appropriate subscript or subscripts to identify the associated colour separation signal channel and/or colour sub-carrier phase. The colour separation signal subscripts are *R* for red, *B* for blue, and *G* for green, and the colour sub-carrier phase subscripts are *U* for *U*-phase and *V* for *V*-phase. The use of an *R* subscript indicates that there are equivalent blue and green channels, subscript *B* and *G* respectively, and the use of a *U* subscript indicates that there is an equivalent *V*-phase channel, unless otherwise indicated.

The use of a bar such as $\overline{50_U}$ for colour sub-carrier square wave signals is the normal Boolean algebra use meaning inversion. Thus $\overline{50_U}$ is the minus *U*-phase colour sub-carrier. Similarly 50_V represents the *V*-phase colour sub-carrier, being + / − on alternate TV lines, while $\overline{50_V}$ is the minus *V*-phase colour sub-carrier, and is − / + on alternate TV lines.

The chorminance signals can be obtained by gating repetitive signals, for example square-wave signals, in *U* and *V* phases at colour sub-carrier frequency, using digital colour separation signals, as described for an apparatus 40 shown in Fig. 3.

In this embodiment the colour-separation signals are single-bit, that is the primary colours, red, green and blue, are either on or off, with no intermediate tones.

In Fig. 3 the red channel only is shown in detail. A *NAND*-gate 42_{RU} has inputs 44_{RU} to which is applied a red separation signal 48_R, and 46_{RU} to which is applied a -*U*-phase colour sub-carrier input $\overline{50_U}$. The output 52_{RU} of the *NAND*-gate 42_{RU} is connected to the cathode of a diode 54_{RU} to switch a defined current to the input 64 of a current summing amplifier 56. The defined current is produced by a resistor 58_{RU} connected at one end to a first reference supply and at the other end to the junction of the anode of the diode 54_{RU} and the emitter of a transistor 60_{RU}. The base of the transistor 60_{RU} is connected to a second reference voltage and the collector of the transistor 60_{RU} is connected to the input 64 of the summing amplifier 56. The current is defined by the quotient of the difference between the first and second reference voltages less the transistor V_{be}, divided by the value of the resistor 58_{RU}. As this current is switched by the -*U*-phase of the colour sub-carrier 50 *U*, and the red-separation signal 48_R, it is controlled by the red-separation signal and in the -*U*-phase of the colour sub-carrier.

A further *NAND*-gate 42_{RV} has applied to an input 44_{RV} the red-separation signal 48_R as above, and to an input 46_{RV} is applied *V*-phase colour sub-carrier input 50_V, the phase of this input being positive and negative on alternate scanning lines for the PAL system, producing an output 52_{RV}. This output is applied to a diode 54_{RV}, resistor 58_{RV} and transistor 60_{RV} connected as above to provide a current, proportional to the red-separation signal 48_R and in the ± *V*-phase of the colour sub-carrier on alternate scanning lines, to the summing amplifier input 64.

The output 52_{RU}, 52_{RV} of the *NAND* gates 42_{RU}, 42_{RV} contain the colour sub-carrier component superimposed on a pedestal of amplitude half the square-wave amplitude, so that the output of the summing amplifier 56 also contains a signal proportional to, half the amplitude of, and inverted with respect to the red separation signal 48_R.

This may be corrected by switching a defined current to the input 64 of the summing amplifier 56, the current being produced by a resistor 58_R connected at one end to the first reference supply and at the other end to the junction of the anode of a switching diode 54_R and the emitter of a transister 60_R. The base of the transistor 60_R is connected to the second reference supply and the collector of the transistor 60_R is connected to the summing amplifier input 64. The cathode of the diode 54_R is connected directly to the red separation signal 48_R,

and hence the current at the collector of the transistor 60_R is controlled by the red separation signal 48_R.

If the correction current is such as to just cancel the pedestal, a bandpass filter will be needed to restrict the bandwidth of the chrominance signal from the output of the summing amplifier 56. A separate summing amplifier is then required to form the luminance signal, the chrominance and luminance signals will then be combined after suitably delaying the luminance signal.

Alternatively, as shown in Fig. 3, the value of resistor 58_R can be chosen so as to produce the correct luminance value for the red separation signal in the output from the amplifier 56. The output of the summing amplifier 56 is then fed to a low-pass filter 66, with a cut-off of about 5.5 MHz for PAL System I. The chrominance signal so generated has a restricted upper sideband, but the lower sideband is not restricted, and the chrominance signal is, as a result, non-standard. No deterioration of the picture produced, due to the signal being non-standard, has been observed in practice. Picture deterioration is a risk, which if not acceptable, will mean that a separate summing amplifier for the luminance signal is required.

To ensure that the summing amplifier 56 operates in a linear manner, a current sink 68 is connected to the input 64.

In addition to the red channel as shown, other inputs 70 to the summing amplifier input 64 are green and blue channels, which are generally similar to the red channel, *U* and *V* components of the colour burst, and the composite sync waveform.

The embodiment of Fig. 3, in addition to being used for production of a colour bar test signal, can be used to produce coloured captions, video-tape recorder clock presentations, computer graphics, text, and displays for video games.

The generation of encoded signals from digital picture information is an extension of the foregoing, where the signals are given the appropriate binary weighting and summed in a single summing amplifier if the non-standard chrominance sidebands described above are acceptable, or in two summing amplifiers if chrominance and luminance signals are handled separately.

Apparaus for such a system using a single summing amplifier is shown in Figs. 4*A* and 4*B*.

An encoding apparatus 100 has red, green and blue channels 102_R, 102_G and 102_B respectively.

Each channel has corresponding digital colour-separation signal inputs 104_{Ra}–104_{Rn}, 104_{Ga}–104_{Gn}, and 104_{Ba}–104_{Bn} respectively, suffices *a*–*n* indicating the digital inputs in decreasing order of significance in each case.

Considering the red channel 102_R, there are two sets of NAND gates 108_{RUa}–108_{RUn}, and 108_{RVa}–108_{RVn}. One input to the corresponding pair of gates of each set is the red digital separation signals 104_{Ra}–104_{Rn} respectively, in decreasing order to significance. The second input $\overline{106}_U$ to the gates 108_{RUa}–108_{RUn} is the -*U*-phase of the colour sub-carrier, and the second input 106_V to the gates 108_{RVa}–108_{RVn} is the ± *V*-phase of the colour sub-carrier on alternate scanning lines.

The output of each of the NAND-gates 108_{RUa}–108_{RUn} and 108_{RVa}–108_{RVn} is connected to a respective resistor-diode-transistor current switching circuit similar to that shown for each of the *NAND*- gates 42_{RU}, 42_{RV} in Fig. 3, comprising resistor 110_{RUa}–110_{RUn} and 110_{RVa}–110_{RVn}, switching diodes 112_{RUa}–112_{RUn} and 112_{RVa}–112_{RVn}, and transistors 114_{RUa}–114_{RUn} and 114_{RVa}–114_{RVn} respectively. Resistor-diode-transistor luminance switching circuits, similar to resistor 58_R switching diode 54_R and transistor 60_R in Fig. 3, comprising resistors 116_{Ra}–116_{Rn}, switching diodes 118_{Ra}–118_{Rn} and transistors 120_{Ra}–120_{Rn}, respectively, have the respective red separation signals 104_{Ra}–104_{Rn} input thereto.

The resistors 110_{RUa}–110_{RUn}, 110_{RVa}–110_{RVn}, 116_{Ra}–116_{Rn}, at the end remote from the junction with the respective diode anode and transistor emitter, are connected to a common first reference supply (not shown). Similarly the bases of the transistors 114_{RUa}–114_{RUn}, 114_{RVa}–114_{RVn}, and 120_{Ra}–120_{Rn} are connected to a common second reference supply (not shown). The collectors of the transistors 114_{RUa}–114_{RUn}, 114_{RVa}–114_{RVn}, and 120_{Ra}–120_{Rn} are connected to the input 122 of a current summing amplifier 124.

The values of the resistors 110_{RUa}–110_{RUn}, 110_{RVa}–110_{RVa} and 116_{Ra}–116_{Rn} are chosen so as to provide a collector current in the respective transistors proportional to the weighting of the respective red separation signal 104_{Ra}–104_{Rn}. The current at the amplifier input 122 is then proportional to the sum of the weighted red separation signals, and a function of the red chrominance and luminance signals.

The blue and green channels 102_B and 102_G respectively are similar to the red channel 102_R, the equivalent components being listed in Table I below, but for reasons of clarity, these components are not in general identified on the drawings.

TABLE I

ITEM	RED CHANNEL 102_R	BLUE CHANNEL 102_R	GREEN CHANNEL 102_G
Separation Signal	104_{Ra}–104_{Rn}	104_{Ba}–104_{Bn}	104_{Ga}–104_{Gn}
NAND-gates: *U*-phase	108_{RUa}–108_{RUn}	108_{BUa}–108_{BUn}	108_{GUa}–108_{GUn}
NAND-gates: *V*-phase	108_{RVa}–108_{RVn}	108_{BVa}–108_{BVn}	108_{GVa}–108_{GVn}
Resistor: *U*-phase	110_{RUa}–110_{RUn}	110_{BUa}–110_{BUn}	110_{GUa}–110_{GUn}
Resistor: *V*-phase	110_{RVa}–110_{RVn}	110_{BVa}–110_{BVn}	110_{GVa}–110_{GVn}
Resistor: luminance	116_{Ra}–116_{Rn}	116_{Ba}–116_{Bn}	116_{Ga}–116_{Gn}
Switching diode *U*-phase	112_{RUa}–112_{RUn}	112_{BUa}–112_{BUn}	112_{GUa}–112_{GUn}
Switching diode *V*-phase	112_{RVa}–112_{RVn}	112_{BVa}–112_{BVn}	112_{GVa}–112_{Gvn}
Switching diode luminance	118_{Ra}–118_{Rn}	118_{Ba}–118_{Bn}	118_{Ga}–118_{Gn}
Transistor: *U*-phase	114_{RUa}–114_{RUn}	114_{BUa}–114_{BUn}	114_{GUa}–114_{GUn}
Transistor: *V*-phase	114_{RVa}–114_{RVn}	114_{BVa}–114_{BVn}	114_{GVa}–114_{GVn}
Transistor: luminance	120_{Ra}–120_{Rn}	120_{Ba}–120_{Bn}	120_{Ga}–120_{Gn}
Colour sub-carrier input: *U*-phase	$\overline{106}_U$	$\overline{106}_U$	106_U
Colour sub-carrier input: *V*-phase	106_V	$\overline{106}_V$	$\overline{106}_V$

The sub-carrier square-wave inputs to the green channel 102_G are -*U*-phase $\overline{106}_U$, and $\mp$ *V*-phase $\overline{160}_V$ on alternate TV lines, to the *NAND*-gates 108_{GUa}–108_{GUn}, and 108_{GVa}–108_{GVn}, respectively. Similarly, the sub-carrier square-wave inputs to the blue channel 102_B are *U*-phase 106_U, and $\mp$ *V*-phase $\overline{106}_V$, to the *NAND*-gates 108_{BUa}–108_{BUn}, and 108_{BVa}–108_{BVn}, respectively.

The collectors of the transistors 114_{GUa}–114_{GUn}, 114_{GVa}–114_{GVn}, 114_{BUa}–114_{BUn}, 114_{BVa}–114_{BVn}, 120_{Ga}–120_{Gn}, and 120_{Ba}–120_{Bn} are commoned and connected to the amplifier input 122.

Also connected to the amplifier input 122, are a colour burst input 126, a composite sync waveform input 128, and a current sink 130. The output of the amplifier 124 is fed to a low-pass filter 132, whose output 134 is the required PAL television signal.

To provide freedom from adjustment accurate quadrature sub-carrier square waves are required. This is most readily done by division from the fourth harmonic of the colour sub-carrier frequency as shown in Fig. 5.

The fourth harmonic of the colour sub-carrier frequency is applied to the input 202 of a first flip-flop 204. The Q, $\bar{Q}$ output 206, 208 of the flip-flop 204 are applied to second and third flip-flops 210, 212 respectively, flip-flop 210 being a *J–K* flip-flop.

The Q, $\bar{Q}$ outputs of the flip-flop 212 form the *U* and -*U* phase sub-carrier square-wave signals 214, 216, respectively, and are also fed to one input of respective exclusive-*OR* gates 218, 220.

The second input of each of the exclusive-*OR* gates 218, 220 is fed by a PAL switch square-wave 222. The outputs of the exclusive-*OR* gates 218, 220 are connected to the *J* and *K* inputs of the flip-flop 210. The Q and Q outputs 224, 226 respectively are the *V*-phase colour sub-carrier square-waves signals, the outputs being 180° out-of-phase with each other, and alternating in phase each TV line.

The fourth-harmonic colour sub-carrier signal may be locked to the station sub-carrier, if this is available, by use of a phase-locked loop. If the equipment is self-contained it may be advantageous to include a crystal master oscillator with a frequency of four or eight times the colour sub-carrier frequency, from which all the remaining frequencies required may be derived.

Use of an encoding apparatus such as is shown in Figs. 4*A* and 4*B* provides the functions of three digital-to-analogue converters and a PAL encoder.

Instantaneous changing from PAL to NTSC standards may be achieved by:

(i) changing the colour sub-carrier frequency;

(ii) removing the PAL switch waveform;

(iii) switching off the *V*-component of the colour-burst; and

(iv) changing the magnitude of the *U*-component of the colour burst.

Such an arrangement would be advantageous in a digital magnetic video recorder for use with PAL or NTSC systems.

Where the apparatus is to be used with the NTSC system only, the *U* and *V*-phase colour sub-carrier square-wave signals may be replaced by *I* and *Q*-phase signals. Band-pass filters of different band width may be applied to the *I* and *Q*-components to enable a full-specification NTSC signal to be produced.

Alternatively, one of the colour sub-carrier square-wave signal phases may be aligned with one of the primary colour vectors, then one set of gates may be omitted. For example, if aligned with the green vector, the *NAND*-gates which have the quadrature signal as an input in the green channel would always have a zero output, and so these gates may be omitted.

The chrominance signal may be generated at a lower sub-carrier frequency, reducing the significance of phase errors. If a sub-carrier frequency of one-quarter of the standard colour sub-carrier freqency is chosen, the lower frequency sub-carrier signals can be obtained from the standard colour sub-carrier frequency by direct sub-division, such as by the method illustrated in Fig. 5. The band width of the chrominance signal will need to be restricted more than usual before it is heterodyned back to its normal position in the frequency spectrum of the television signal by mixing with a local oscillator signal having a frequency of three-quarters or five-quarters of the standard colour sub-carrier frequency.

The heterodyning step may be avoided if the lower non-standard sub-carrier frequency is an odd sub-multiple of the colour sub-carrier frequency, preferably one-third. A band-pass filter at the output of the chrominance summing amplifier will then select that harmonic of the non-standard sub-carrier frequency which is at the standard colour sub-carrier frequency, which harmonic carries the same information as the fundamental frequency but at a lower amplitude. To provide the lower sub-carrier frequency signals with the required quadrature relationships the use of a phase-locked loop or regenerative divider will be necessary.

Square-waves in the red, green and blue phases may be obtained directly, making necessary only one set of gates for each component and dispensing with the need for vector addition. The phase may be obtained by division from one hundred and five times the colour sub-carrier frequency, that is 370 MHz for NTSC and 465 MHz for PAL. If the angular phase separations as a fraction of a circle are

$$\frac{40}{105}, \frac{31}{105} \text{ and } \frac{34}{105}$$

for red/green, green/blue, and blue/red, respectively, then the error is less than 0.2° in each case. This technique can be combined with the harmonic filtering described above. In this case with square-waves at 35, 21 or 15 times the colour sub-carrier frequency, the third, fifth or seventh harmonic, respectively, of the summed square-wave signal is used as the chrominance signal.

The array of gates shown in Figs. 4*A* and 4*B* may be halved by a technique illustrated and described with reference to Figs. 6 and 7.

Three phases 306, 308, 310_U of a rectangular wave at colour sub-carrier frequency, the phases being 120° apart, are derived by division of the output from a master oscillator 302 running at three times colour sub-carrier frequency in a divider 304. Two of these phases 306, 308 are fed to an electronic changeover switch 312 controlled by a control signal 314 at half the line scan frequency, to give outputs 310_S and 310_T, outputs 310_S and 310_T being interchanged line by line.

The outputs 310_S, 310_T and 310_U are then fed to one input of each *NAND*-gate of respective sets of *NAND*-gates 316_{Sa}–316_{Sn}, 316_{Ta}–316_{Tn} and 316_{Ua}–316_{Un}.

The red, green and blue digital signals 318_{Ra}–318_{Rn}, 318_{Ga}–318_{Gn} and 318_{Ba}–318_{Bn} respectively, are fed to a linear matrix 320 which transforms the red, green and blue signals to new primary colours, designated *S*, *T* and *U*, the signals after transform becoming 322_{Sa}–322_{Sn}, 322_{Ta}–322_{Tn} and 322_{Ua}–322_{Un}, which are fed to the other input of the respective *NAND*-gates

316_{Sa}–316_{Sn}, 316_{Ta}–316_{Tn} and 316_{Ua}–316_{Un} respectively.

If the *U*-phase component is identical to the *U*-component of the PAL signal, so as to simplify *V*-axis switching of the PAL system, then

$$S = +\frac{1}{2}.\sqrt{3}\ \frac{(R'-Y')}{1.14} - \frac{1}{2}.\ \frac{(B'-Y')}{2.03}$$

$$T = -\frac{1}{2}.\sqrt{3}\ \frac{(R'-R')}{1.14} - \frac{1}{2}.\ \frac{(B'-Y')}{2.03}$$

$$U = \frac{(B'-Y')}{2.03}$$

or in terms of *R'*, *G'* and *B'*.

$$S = 0.606R' - 0.301G' - 0.305B'$$
$$T = -0.459R' + 0.590G' - 0.131B'$$
$$U = -0.147R' - 0.289G' + 0.436B'$$

and the *V*-axis switching necessary for the PAL-system can be obtained by the interchanging of 310_S and 310_T referred to above.

The linear matrix 320 may be implemented readily in digital form, and where additionally a signal processing matrix is required at this point for other purposes, the two matrices may be combined.

The output of each of the *NAND*-gates 316_{Sa}–316_{Sn}, 316_{Ta}–316_{Tn}, and 316_{Ua}–316_{Un} is connected to a respective resistor-diode-transistor current switching circuit similar to these shown for the embodiments of Fig. 3, and 4*A* and 4*B* their outputs being connected to the input 122′ of an amplifier 124′.

Resistor-diode-transistor luminance switching circuits, similar to these of the embodiments of Figs. 3 and 4*A* and 4*B* have the *R, G, B* or *S, T, U* signals fed thereto, and these are also fed to the input 122′ of the amplifier 124′ by a line 324. A colour burst input 126′, a composite sync waveform input 128′ and a current sink 130′ are also connected to the amplifier input 122′.

The output of the amplifier 124′ is then fed to a low-pass filter 132′, the output 134′ of which is the required TV signal.

The use of either *R, G, B* or *S, T, U* signals for driving the luminance switching circuits in this embodiment is also possible in the earlier embodiments, it being necessary simply to adjust the values of the resistors in the switching circuits to give the appropriate weighting in each case. It is possible to reduce the number of luminance switching circuits to one set, rather then having one set for each primary colour component. This may be done by matrixing the components and producing a digital luminance signal, for example as a fourth output *Y* (not shown) for the matrix 320 of Fig. 7. While this reduces the number of luminance switching circuits, it is likely not to be a worth-while exercise due to the requirement for a complex high-speed marix circuit to transform from *R, G, B* or *S, T, U* to *Y*.

Figure 6 shows the vector relationships between the *S, T* and *U* vectors and the *R, G* and *B* vectors. As the *S, T* and *U* sub-carrier signals are produced by dividing the output of the master oscillator 302 by three, they are rectangular waves having a mark-space ratio of 1:2, and due allowance must be made for the fact that the harmonic content differs from that for a square wave.

The same criteria for selection of the relationship of the clock frequency of the digital television signal and the colour sub-carrier frequency apply as before. A frequency of three times colour sub-carrier frequency is advantageous for 625-line signals, because at 13.3 MHz it is high enough to define a 6 MHz bandwidth video signal fully, and to provide sufficient magin for filtering between the 6 MHz frequency limit and the Nyquist limit of 6.6 MHz.

The effect of a frequency of three times colour sub-carrier frequency is that the three 1:2 mark-space ratio rectangular waves form an interleaved set, and since the encoding process is symmetrical the sample sets representing *S, T* and *U* require the same weighting, and the design of the summing amplifier and digital-to-analogue converter are simplified.

A similar argument may be applied to digital signals of four times colour sub-carrier frequency with $\pm$U and $\pm$V sub-carriers if the sub-carrier reference signals are modified to be 1:3 mark-space ratio rectangular waves.

An alternative means of generating digitally the phase-shifts between red, green and blue signals will be described with reference to Figs. 8 and 9.

If a master oscillator is run at 21 times colour sub-carrier frequency, phase-locked to an external colour sub-carrier if necessary, and eight cycles of this oscillator frequency define the angle between the green and red vectors, an error of less than 0.07 degrees occurs. Two signals at sub-carrier frequency, each derived from the master oscillator by division by 21 and with a phase-shift defined by the eight cycle difference may be used to feed one set of each of the red and green chrominance gates of Figs. 4*A* and 4*B*, for example, 108_{RUa}–108_{RUn} and 108_{GUa}–108_{GUn} respectively.

The phase of the blue vector is not conveniently related to the red and green vectors in terms of 1/21 of a circle, but it can be obtained from the $-G$ and $-R$ components. With appropriate changes in the weighting factors, the inverted green and red colour sub-carrier waves may be used in place of the U and V components of the blue vector.

The required square-waves at colour sub-carrier frequency can be obtained by counting 10 1/2 cycles of the master oscillator to define both marks and space, starting from cycle '0' for red and cycle '8' for green. Alternatively, latches can be set at 0, 8 and reset at 10 1/2, 18 1/2 respectively to define the two waves. The use of square-waves as discussed for other embodiments is not essential. Rectangular waves having mark/space ratios other than 1:1 can be used provided that due allowance is made for the phases and relative amplitudes of the fundamental frequency components or of the appropriate hamonic in computing the weighting factors, in addition even harmonics are available as well.

Blue blue vector, as shown in Fig. 8, can be resolved into components of -1.410 of the red square-wave and -1.317 of the green square wave. This resolution is in terms of the red/green cycle actually used, $8/21 \times 360° = 137.14°$, and not the theoretical value of 137.21°. The 0.07 error has been distributed 0.04 to the red/blue angle and 0.03° to the green/blue angle.

This provides an NTSC signal, but for PAL axis-switching is required.

If as shown in Fig. 9, a circle as divided into 21 equal sectors by radii numbered from 400 to 420, then radius 400 may be placed along the U-axis. Radius 406 then occurs at 102.86° and radius 14 at 240°, clockwise of the true positions of red and green by 0.61° and 0.68°, respectively. If blue is now generated as described above in connection with Fig. 8, it will be at 346.44°, 0.66° clockwise of its true position. The mean of the three errors of 0.61°, 0.68° and 0.66° is 0.65° clockwise, and since this is a "built in" error in the signal, a receiver is unable to correct for it. If it could be presented to the receiver as a "transmission" error, then the receiver could correct for it. This may be achieved by moving the colour burst clockwise 0.65° on both "forward" and "reverse" lines, to lie at 134.35° and 224.35° on alternate lines, thus moving the mean phase of the receiver reference oscillator 0.65° and obtaining correct demodulation. A slight unbalance between 'odd' and 'even' colour bursts has been introduced, but as the deviation from nominal value of either component does not exceed (1 – cos 0.65°) or 0.000064 the effect is negligible. The error correcting action of the receiver or monitor decoder will give displayed colours of the correct hue, but with saturation reduced by this factor, and the effect will not be discernible.

This embodiment uses 21 times colour sub-carrier frequency and four sets of gates, as opposed to considerably higher frequences (105) times colour sub-carrier frequency) and three sets of gates or lower frequencies and six sets of gates.

CLAIMS

1. A method or producing a colour television signal by switching a repetitive signal as defined herein according to digital colour-separation signals and summing the switched repetitive signal and colour separation signals.

2. A method as claimed in Claim 1, wherein the repetitive signal has a fundamental frequency at the colour sub-carrier frequency of the colour television signal.

3. A method as claimed in Claim 1, wherein the repetitive signal is an integral sub-multiple of the colour sub-carrier frequency of the colour television signal and the summed signals are passed through a band-pass filter whose pass-band is centred on the colour sub-carrier frequency.

4. A method as claimed in Claim 1, 2 or 3, wherein the repetitive signal is a square wave.

5. A method as claimed in Claim 1 and substantially as hereinbefore described.

6. An apparatus for producing a colour television signal from digital colour-separation signals comprising a source of a repetitive signal as defined herein, switching means for switching the repetitive signal in response to the colour-separation signals and summing means for summing the switched repetitive signal and the colour-separation signals.

7. An apparatus for producing a colour-television signal from digital colour-separation signals substantially as hereinbefore described, with reference to and as illustrated in Figs. 1, 2 and 3, or Figs. 4*A* and 4*B*, or Figs. 6 and 7, or Figs. 1, 2 and 3 as modified by Fig. 5, or Figs. 4*A* and

4 *B* as modified by Fig. 5, or Figs. 6 and 7 as modified by Figs. 8 and 9.

8. A colour television signal when produced by the method of any one of Claims 1 to 5, or using the apparatus of Claims 6 or 7.

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